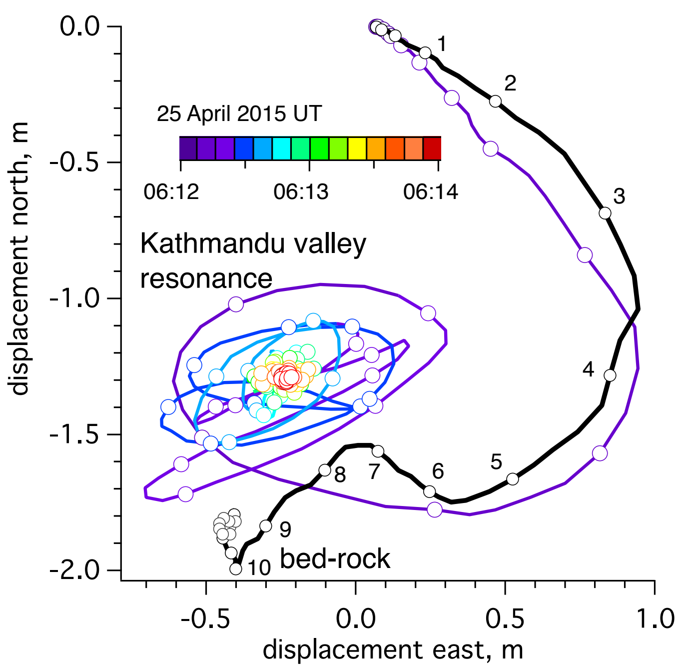
Kathmandu Valley Shaking Intensities Gorkha earthquake 25 April 2015

Throughout most of the Kathmandu valley shaking intensity was less than EMS 7 but in some places buildings were exposed to intensity 8 or greater. These were on ridges or on the summits of small hills, or in regions of former swamps near rivers. In two cases EMS 5 was reported, although there may have been many more since these were places where no damage caught the attention of those quantifying shaking intensity. The inputs to the valley consisted of low amplitude high frequency shaking and very large low frequency translation.



Two GPS receivers recorded the translation, upheaval & oscillation of the Kathmandu valley sediments each 0.2 s; KKN4 (black on rock) and NAST (colored time-code on sediments). In map view the displacements input to the valley describe a large sickle-shaped path that shifted the northern edge of the valley 2 m south in 10 seconds (numbers indicate 1 second intervals). Partly because the slip pulse beneath the valley propagates southward and partly due to a phase lag in the sediments the sediments respond a few seconds later. After the tenth second the sediments continue to oscillate, initially with a 7 s forced frequency, and after two cycles with 5 s and 3.5 s resonant oscillations that continue for 2 minutes with amplitudes exceeding 1 cm. At the same time the valley rises by 1 m in the north and by a lesser amount in the south. The uplift is caused partly by translation southwards and upwards on a shallow ramp, and partly by elastic compression caused by the termination of rupture propagation near the southern edge of the valley.

A movie showing the effects of this oscillation on pedestrians can be seen here.
https://www.dropbox.com/s/v9f25joyunzwqsh/Gorkha Motion 1.1.m4v?dl=0

The data in the movie and presented above were processed by David Mencin from the raw GPS data archived in UNAVCO. In the first few seconds, high frequency, low amplitude shaking precedes the translation of the valley and causes birds to take flight. High frequencies throughout have amplitudes of less than a few cm, negligible compared to the 50-cm-amplitude, 5-second-period oscillations in the city.

Galetzka J., and 30 other authors (2015) Slip pulse and resonance of Kathmandu basin during the 2015 Mw 7.8 Gorkha earthquake, Nepal imaged with geodesy *Science* 6 Aug. 2015 10.1126/science.aac6383.

Thamel

In Thamel numerous very weak traditional buildings assembled from fired bricks, interspersed with wooden beams and ornate window assemblies survived the earthquake unscathed. This was a surprise since the region has for many years been cited as a worst case region for potential earthquake damage: narrow streets, a rats nest of overhead wires, and many weak masonry buildings in tottering condition. In contrast the Durbar square heritage buildings fared poorly, as did a small number (estimated 1 in 500) of traditional buildings interspersed throughout the Thamel district. Tall walls collapsed as did electrical poles whose steel had corroded within their concrete sheaths. Damage to concrete frame buildings was rare.

One example of a partial 7- story soft story RCC collapse is described. The owner's father insisted on a well constructed building. A foundation raft of concrete 7 feet thick was apparently poured (the owner described this as a solid block but the amount of concrete required for its 7 m width and 20 m depth from the street would seem excessive). Engineers were involved in the design, and the assembly was inspected at every stage by government building inspectors. Finally the building was insured against earthquake damage. The building was supported by columns on each side and by five or more extending back from the street. During the earthquake three of the left columns fragmented (weak cement and insufficient stirrups) and the building tilted and leaned against what appears to be an identical construction with just 6 stories. This adjacent building was damaged by the sideways impact of the 7 story building in the mainshock, and further damaged in aftershocks. The owner emptied the building and dismantled it top down over a period of 6 weeks. Some or all of the adjacent building needed dismantling. No other RCC buildings were damaged within almost a 1 km radius.

A rare RCC collapse in Thamel –left a week after the earthquake. Right partly dismantled two months after the earthquake. Center: front left hand column collapse.

South of Thamel the Bhim Sen tower collapsed killing all visitors to the building (midday Saturday). This is third time the tower has been damaged but only the second time it was raized to the ground (1833 and 2015). Buildings in the region immediately north of Thamel were not damaged except near the river and damage became intense near the ring road bridge across the Bishnumati river and the bus station. Here damage to RCC buildings was severe but over a limited region. Undamaged RCC strucutres could be found within 200 m of those with severe damage.

Base of Bhim Sen Tower after it had been cleared of debris. The Bhim Sen tower (one of two) was constructed in 1825 and reconstructed after the 1833 earthquake. Its sister tower was not reconstructed. It escaped damage in 1866 but partly collapsed in the 1934 Bihar/Nepal earthquake and was again repaired, but totally collapsed in 2015. The Bhim Sen tower was most recently known as the Dharahara tower.

Left views of the exposed ceilings of RCC building above the west bank of the Bishnumati River (1 km south of the bridge right) that has topped downhill and rotated 90° during collapse. A cluster of buildings here (less than 5% of the total), suffered lower story damage (e.g. lower right) but the bulk of the surrounding RCC buildings were undamaged. Brittle steel was evident in the columns with insufficient and poorly tied stirrups.

A ridge north of the Syambunath temple included numerous damaged buildings. The temple complex had been severely shaken, compared to the base of the hill on which it was constructed.